Lab 3: Maps 100 pts

Introduction

Topographic maps are one of the most important tools for studying landforms and the processes that shape them. These maps are two-dimensional scale representations of the Earth's surface that show the sizes, configurations, and spatial relationships of landforms and cultural features in great detail. They allow very accurate measurement of elevations and horizontal distances.

The advent of Global Positioning Systems (GPS) and Geographic information Systems (GIS) has revolutionized the use of topographic and other maps by many businesses and by the scientific community. These technologies require that the users have a basic understanding of map-making principles. This lab will focus on topographic maps, but many of the principles that apply to topographic maps are useful for interpreting maps in general.

What are GPS and GIS? GPS is a navigation systems based on the position of satellites in space. GPS receivers process signals from satellites in known positions and use triangulation to locate points on the Earth's surface. For example, some delivery services now keep track of the position of their trucks by using GPS technology, and ships at sea use it to determine if they are on course. Many people use GPS to locate themselves while hiking, fishing, etc. Geologists use very precise GPS measurements to keep track of motion along faults before and after earthquakes. This lab includes what you need to know about topographic maps so that they can be used in conjunction with a GPS receiver. GIS manages data acquired by GPS and other information on a digitized base map. It is a very powerful tool for analyzing spatial data.

Part 1: Basic facts about maps

USGS Topographic maps

This lab will focus on US Geological Survey topographic maps. Although they are published in a variety of formats (including digital), the most common maps are the 7.5 minute quadrangle series. These maps are bounded by lines of latitude that are 7.5' apart (top and bottom boundaries of the map) and lines of longitude that are also 7.5' apart (east and west edges of the map). These maps are published at scales of 1:24,000 (1 inch = 2000 ft) or 1:25,000 (1 cm = 0.25 km). The detail they show is useful for geological mapping, engineering, local area planning and recreational purposes. It takes about 57,000 maps to cover the conterminous 48 states and complete 7.5' coverage is available for all states except Alaska. A similar series of maps known as 15' quadrangles has been abandoned, but 15' quadrangles are still available for some areas.

Map Datum

All maps have a reference point from which the location of everything on the map is measured. This is referred to as the datum. Before GPS, most map users were rarely concerned with the datum used for a particular map. However, GPS locations are determined from satellites in space, and in order for the receiver to be using the same coordinates as on the map, it must be told the datum.

There are literally hundreds of choices of map datums for mapmakers to use. Map users in the US are most likely to encounter these:

World Geodetic System 1984 (WGS 84) is a datum for the entire globe as defined by GPS

North American Datum 1983 (NAD 83) is a new standard for US maps

North America Datum 1927 Continental (NAD 27) was used for most US and Canadian maps currently in circulation

Map datum information is printed on the maps and may be found in the lower lef-hand corner of most USGS topographic maps.

Map Coordinate Systems

Depending on the task at hand, various methods are used for locating a position on a map. For example, you may locate a friend's house on a map by using the street address. However, this would not be a suitable technique for specifying the location of a mountain peak. For most geological applications, a positioning scheme that is independent of man-made features such as roads or political boundaries is more practical. Historically, the longitude and latitude grid has been used for this purpose, but it is now commonly replaced by other systems such as the Universal Transverse Mercator (UTM) grid. The UTM system is especially convenient for use with GPS receivers. Topographic maps produced by the USGS are prepared so that either latitude/longitude or UTM grids can be used. Both coordinate systems are introduced here.

Latitude & Longitude

Latitude and longitude is a grid of north-south and east-west coordinate lines numbered so that for any given latitude and longitude value one point, and one point only, is described on earth.

Lines of longitude are great circles that encircle the globe in a north-south direction and pass through the poles (Figure 1). These lines are also called meridians and longitude positions are given with reference to the Prime Meridian which passes through Greenwich, England. The prime Meridian is designated as 0 degrees longitude. Other positions of longitude are designated according to the number of degrees of arc they are to the east or west of the Prime Meridian. The "back-side" of the prime meridian is 180º east or west and is mostly coincident with the International Date Line.

Latitude is measured with reference to the equator which is designated as 0 º latitude, whereas the poles are designated as 90º north and 90º south (Figure 2). Except for the equator, lines of longitude are small circles and they are parallel to the equator.

Lab 3: Maps

Coordinates are usually given as latitude, hemisphere; longitude, hemisphere. For example, the position of Pasadena is about 34º North, 118º West, and the position of Sydney, Australia is about 34º South, 151º East.

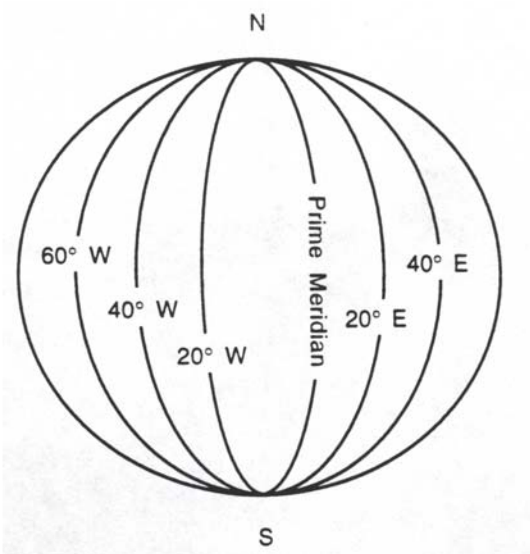


Figure 1: Longitude measured east or west of Greenwich, England

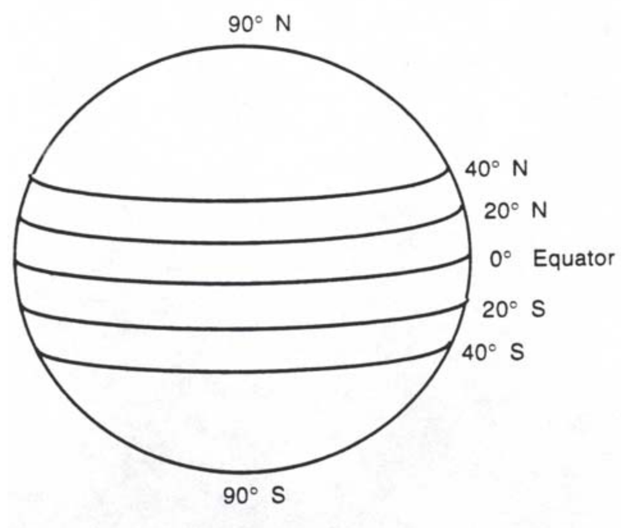


Figure 2: Latitude measured north and south of the equator

To locate positions more precisely the degrees are subdivided into minutes and seconds. There are 60 minutes (60’) in each degree and 60 seconds (60”) in each minute. In other words:

1º = 60’ and 1’ = 60”

For example, if you were giving the location of the Rose Bowl (instead of Pasadena generally), you would need to be more precise than “about 34º N, 118ºW”. The Rose Bowl 50 yard line is at 34º9’41”N, 118º10’0”W. Degrees of latitude and longitude may also be subdivided into decimal fractions. Using this method, the 50 yard line is 34.161ºN, 118.167ºW. (The Rose Bowl is a conspicuous feature on the Pasadena quadrangle map in the lab).

Universal Transverse Mercator (UTM) Grid

This grid divides the Earth into 60 zones based on meridians (lines of longitude). Each zone is 6º wide and the zones are numbered 1-60 starting with the 180º meridian going east (Figure 3). The zones extend from 84º N latitude to 80º S, but they don’t go to the poles because of the convergence of longitude lines at the poles. (Polar navigators use the special Universal Polar Stereographic coordinates). The portion of the UTM grid that covers the conterminous 48 United States comprises 10 zones.

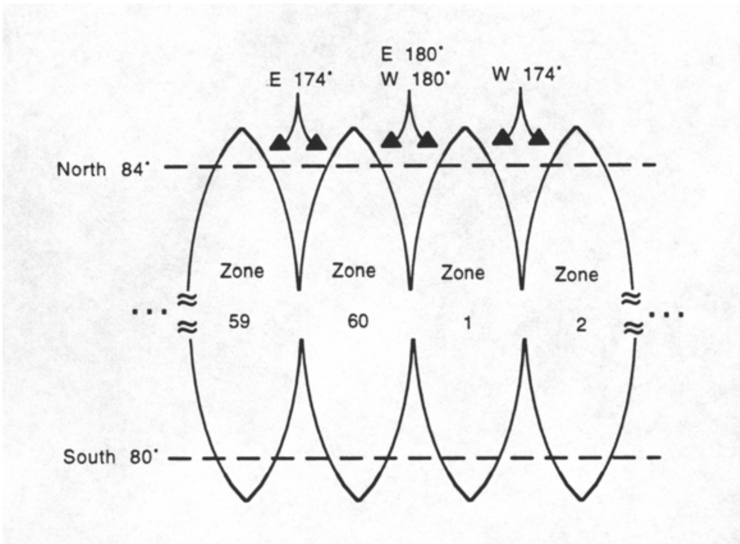


Figure 3: Part of the 60 zones used in a universal transverse mercator projection. Note that the zones end at 84 degrees North and 80 degrees South.

UTM coordinates are given in terms of "eastings" and "northings". Within each zone there is a zone meridian, and its intersection with the equator serves as the reference for the coordinates within a zone (Figure 4). The zone meridian is always in the middle of the zone, that is 3º from either side. The zone meridian is always labeled $^{5}\mathbf{00}^{000}$m.E (or 500,000 m). The value of the easting coordinate can be used to determine the distance in meters from the zone meridian. For example, the coordinate $^{5}\mathbf{02}^{437}$m.E (the equivalent of 500,000 + 2,437) is 2,437 meters (or 2.437 km) east of the zone meridian, whereas the coordinate $^{3}\mathbf{84}^{300}$m.E is 500,000-384300 = 115,700 m (or 115.7 km) west of the zone meridian. This means that starting from the western edge of the zone, the numerical value of the easting coordinate always increases as you move east.

Northing coordinates are measured from the equator. For locations in the Northern Hemisphere, the value for the equator is $^{00}\mathbf{00}^{000}$m.N. For example, a northing of $^{41}\mathbf{15}^{000}$m.N for the Northern Hemisphere would indicate a location 4,115,000 m (4,115 km) north of the equator. The number increases from the Equator to the North Pole. This system is slightly different for the Southern Hemisphere, and there is some ambiguity because the same northing number can be used for a location above or below the equator. To be unambiguous, the northing must also specify which hemisphere. The US Military Grid Reference System (MGRS) subdivides the UTM zones into bands of latitude so that this ambiguity is eliminated. As shown in Figure 4, sections designated C through M are south of the equator and N through X are north of the equator.

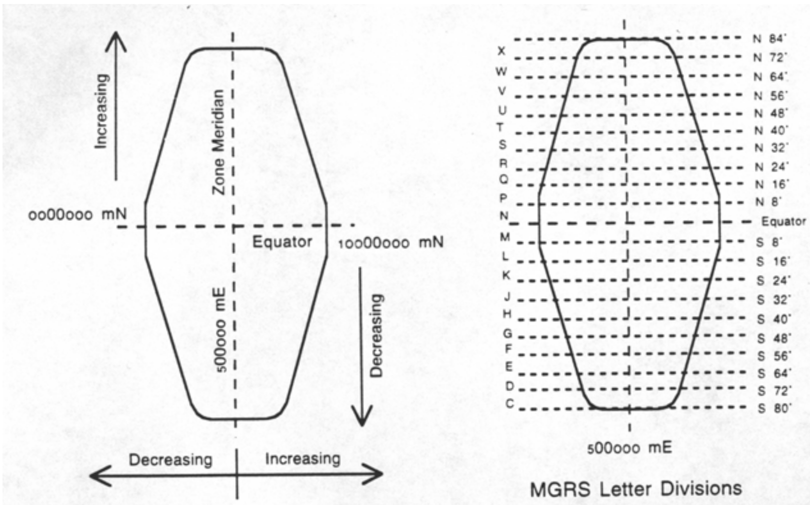


Figure 4: Numbering directions from zone meridian and MGRS letter subdivisions of a zone.

In UTM coordinates the location of Pasadena is about $^{39}\mathbf{6}^{000}$m.E, $^{37}\mathbf{77}^{000}$m.N and the location of the Rose Bowl (near the 50 yard line) is located more precisely at $^{39}\mathbf{2}^{580}$m.E, $^{37}\mathbf{80}^{460}$m.N. Eastings are always given before northings. If you were communicating with someone who had no idea where Pasadena was, the coordinates should be preceded with 11 S. The letter S is the MGRS indication that the location is north of the equator between 32 and 40 degrees, and the 11 is the UTM grid zone number. Maps with UTM grid information give their zone number with the datum.

Sometimes UTM coordinates are given in abbreviated form. Not all the digits are given for less precise locations. For example, $^{41}\mathbf{15}^{000}$m.N might be truncated to $^{41}\mathbf{15}$ N for an approximate location. Other times, the easting and northing are combined as one number with the first half of the digits belonging to the easting, and the second half belonging to the northing. So the location of Pasadena could also be given as approximately 03963777 with the first 4 digits giving the easting and the last 4 digits giving the northing. The location of the Rose Bowl can be given as 03925803780460 with the first 7 digits giving the easting and the last seven giving the northing.

Where is North?

Most maps are printed with north at the top. This is true for all USGS 7.5 minute maps, which are also printed so that the east and west (left and right) boundaries are lines of longitude. However, if you are using a compass with a map, it is important to know that the compass needle does not point to true north. Instead, it points to magnetic north which is offset from the geographic north pole. The angular difference between the two is called the magnetic declination (Figure 5). The magnetic declination is shown on the maps by a diagram such as Figure 6. In this diagram, magnetic north (MN) is 14º east of true north (shown by a star). It should be noted that magnetic declination varies from year to year; therefore, all declination measurements include a date. Figure 6 also shows that grid north (GN, the orientation of the UTM grid lines) is 40' west of true north.

Figure 5

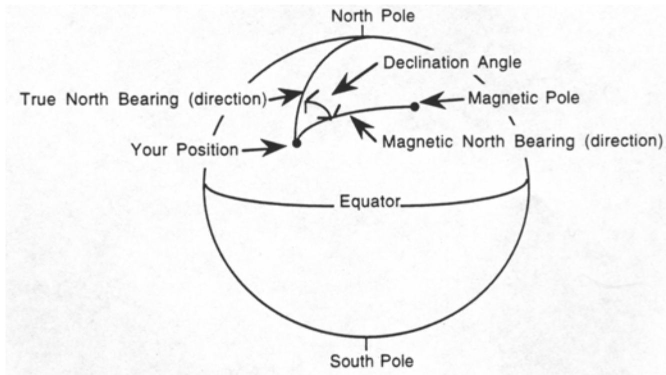
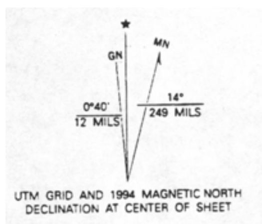


Figure 6



How big are things shown on the map?

Map scales indicate how much larger features are in reality than they are on the map. There are two ways of indicating scale. One is a graphical scale where a bar graph indicates how long kilometers, miles, meters, or feet are on the map. The other is a ratio scale which is designated numerically either in fraction or ratio form. For example, the metric 7.5 minute scale can be expressed as 1/25,000 (fraction form) or 1:25,000 (ratio form). This indicates how much larger the distances are in reality than they are on the map. For example, for a scale of 1:25,000, a distance of 1 cm on the map would be 25,000 cm (0r 250 m or 0.25 km) on the actual land depicted by the map. Many 7.4 minute quadrangles have not yet been converted to metric and they have a scale of 1:24,000.

Cultural and Natural features on topographic maps

Cultural features on topographic maps are shown in red, black, or purple. Light red shaded areas indicate regions of solid or almost solid construction and only landmark buildings are shown. Different classifications of roads are also indicated.

Natural features are shown in a variety of colors. Water (ocean, rivers, lakes, swamps) and ice (glaciers and snowfields) are shown in various blue patterns. Surface features (glacial moraines, sand dunes, mine dumps) are shown with brown patterns, and green patterns indicate different kinds of vegetation. Contour liens are shown in brown. Many of the standard symbols are shown in the flyer "Topographic Map symbols" which is available in the lab.

Lab 3: Maps

How is topography indicated on maps?

Elevation and relief

Elevation is the vertical distance above or below some datum plane, normally taken as mean sea level (0 meters elevation). **Relief** is the difference in elevation between two points in a given region (usually the highest and lowest).

The best way to express elevation and differences in elevation is by means of contour lines. These are lines (brown on the map) that connect points of equal elevation. *All points on a contour lie are at the same elevation.* Therefore, contour lines do not cross because one point cannot have two different elevations.

The concept of contour lines is best understood by imagining an island in the ocean. If you were to point a line around the island at mean sea level (0 m) you would generate a contour line since all of the points are at the same elevation. If the island were submerged exactly 100 m, a new shoreline would result. Every point on this new shoreline would be of the same elevation and exactly 100 m above the original paint line. If you were again to paint the new shoreline on the island, a second contour line would be generated. If this process were repeated at 100-m intervals until the island was completely submerged, and then the water level dropped back to it's original position, the island would be covered with paint lines connecting points of equal elevation (contour lines). An aerial view of the island would be the equivalent of a contour or topographic map (see figure 7)

The vertical interval at which these contour lines are drawn is the contour interval. The contour interval of a topographic map shown on Figure 7 is 100 meters. On topographic map sheets, the contour interval is given on the lower margin of the map next to the scale. Usually, every 4th or 5th line is darkened and labeled to serve as a guide when determining elevation. If a point lies between two contours, interpolate to determine the elevation. However, bear in mind that contours are plotted to an accuracy of ½ one contour interval, so do not work needlessly on false accuracy.

The spacing of contour lines on a topographic map gives you clues about the slope of the surface. When contour lines are close together, such as the ones on the left end of the island in Figure 7, a steep slope is indicated. On the right end of the island, the contour lines are more widely spaced indicating a comparatively gentle slope.

Another characteristic of contour lines is that they "V" upstream. Notice on the island map in Figure 7 that the contour lines come to a point as they go across the streams (dashed lines).

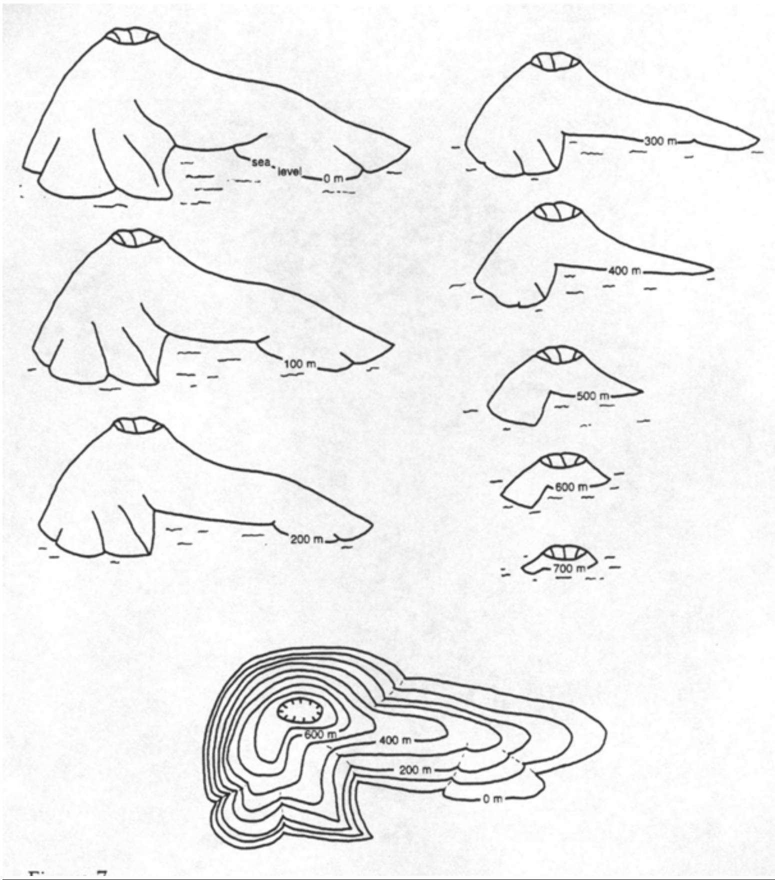


Figure 7

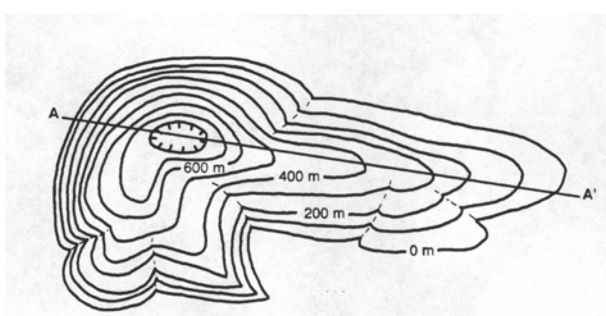
Part II: Using Topographic Maps

Topographic profiles

A topographic profile is a vertical section or side view through a portion of a topographic map that illustrates the shape of various landforms. It is easily constructed from the information on a topographic map as in the example below.

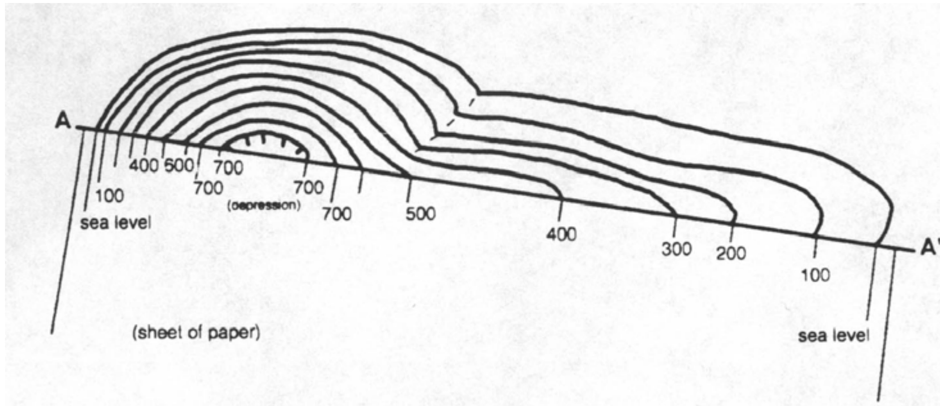
1. Select a line of profile and draw the line on the map (A-A' in Figure 8).

Figure 8



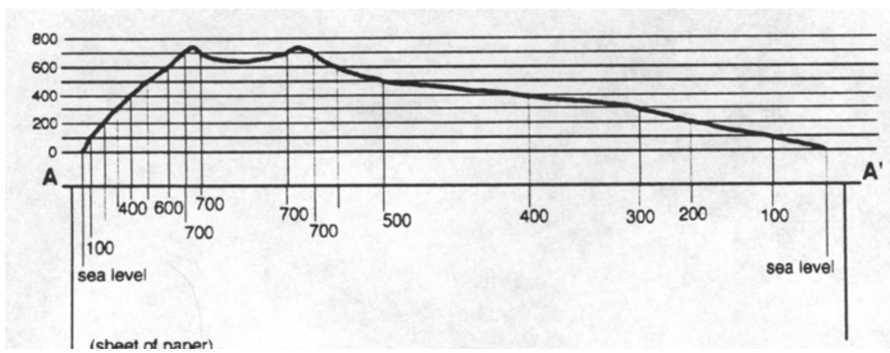
2. Place the edge of a piece of paper along the line. Mark the positions of the ends of the line. Without allowing the paper to move, mark the position of the contour lines where they meet the paper and note the elevation of the lines (Figure 9).

Figure 9



3. Place the paper below a set of ruled lines marked with the appropriate elevations (Figure 10). Then for each mark on the paper, extend a line up to the elevation of the contour line represented by the mark. Last, draw a line connecting the topes of the extended lines to produce the profile.

Figure 10

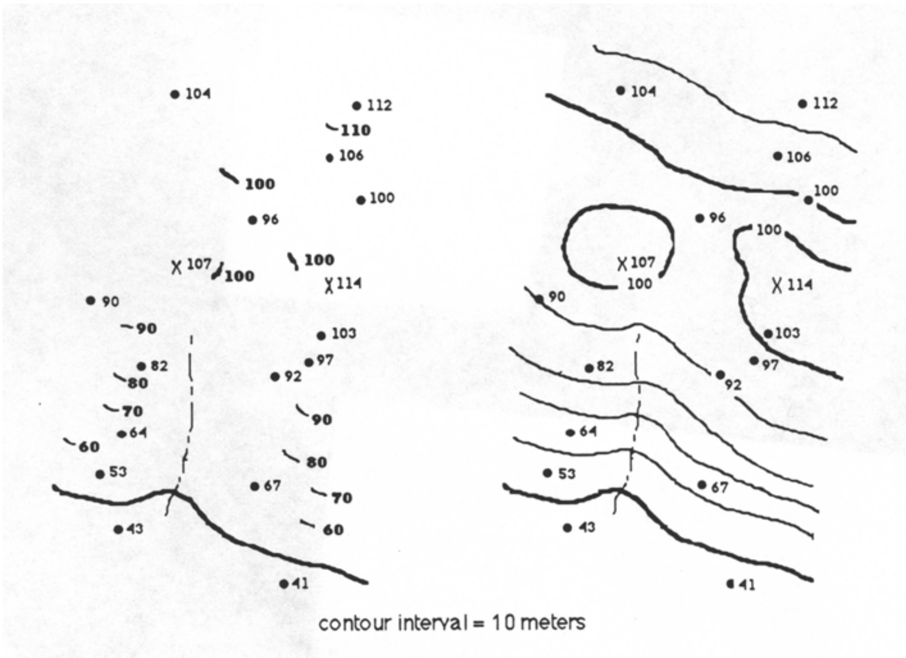


Bear in mind that this is a hypothetical diagram intended to show one technique for constructing a profile. The relative sizes of the vertical and horizontal scales have note been considered.

Constructing Topographic Maps

It is possible to construct a topographic map of an area if enough elevation points within that area are known and accurately located. The basis for making these maps is that if you assume a contour interval of 10 m and you move from a point 105 m in elevation to a second point 146 m in elevation, you will have crossed 4 contour lines (110, 120, 130, 140 m). If we have a map with many known elevations plotted on it, you could create points between the known elevations in multiples of the contour interval as illustrated below (figure 11). It is then possible to connect all of the points of equal elevation with contour lines and produce a topographic map. The only important point to remember is to always use multiples of the contour interval when interpolating between known elevations.

Figure 11



Remember that contour lines never cross, merge or split.

Lab 3: Maps Exercise ***Name_______________***

Procedure

Carefully read and understand the material in Parts 1 and 2 of this lab exercise. Inspect the appendix of your textbook for conversion factors that allow you to convert miles to kilometers, feet to meters, etc. Now you are ready to complete the lab exercise. When answering the questions that follow, **DO NOT** mark on the maps provided in lab!

Questions/Exercises

Read the introduction to this lab to answer the following questions.

1. If something has "low relief", what does this mean? ***(2 pts)***

   ____

   ____

2. Can something with "low relief" be at high elevation? Why? ***(3 pts)***

   ____

   ____

3. Name something in southern California with high elevation. ***(1 pt)***

   ____

4. Why must magnetic north be measured on a yearly basis? Must geographic north be measured on a yearly basis as well? ***(3 pts)***

   ____

   ____

5. Other than oceans, what features are typically shown in blue patterns? ***(2 pts)***

   ____

6. How could you tell a glacier apart from a lake on a topographic map? ***(2 pts)***

   ____

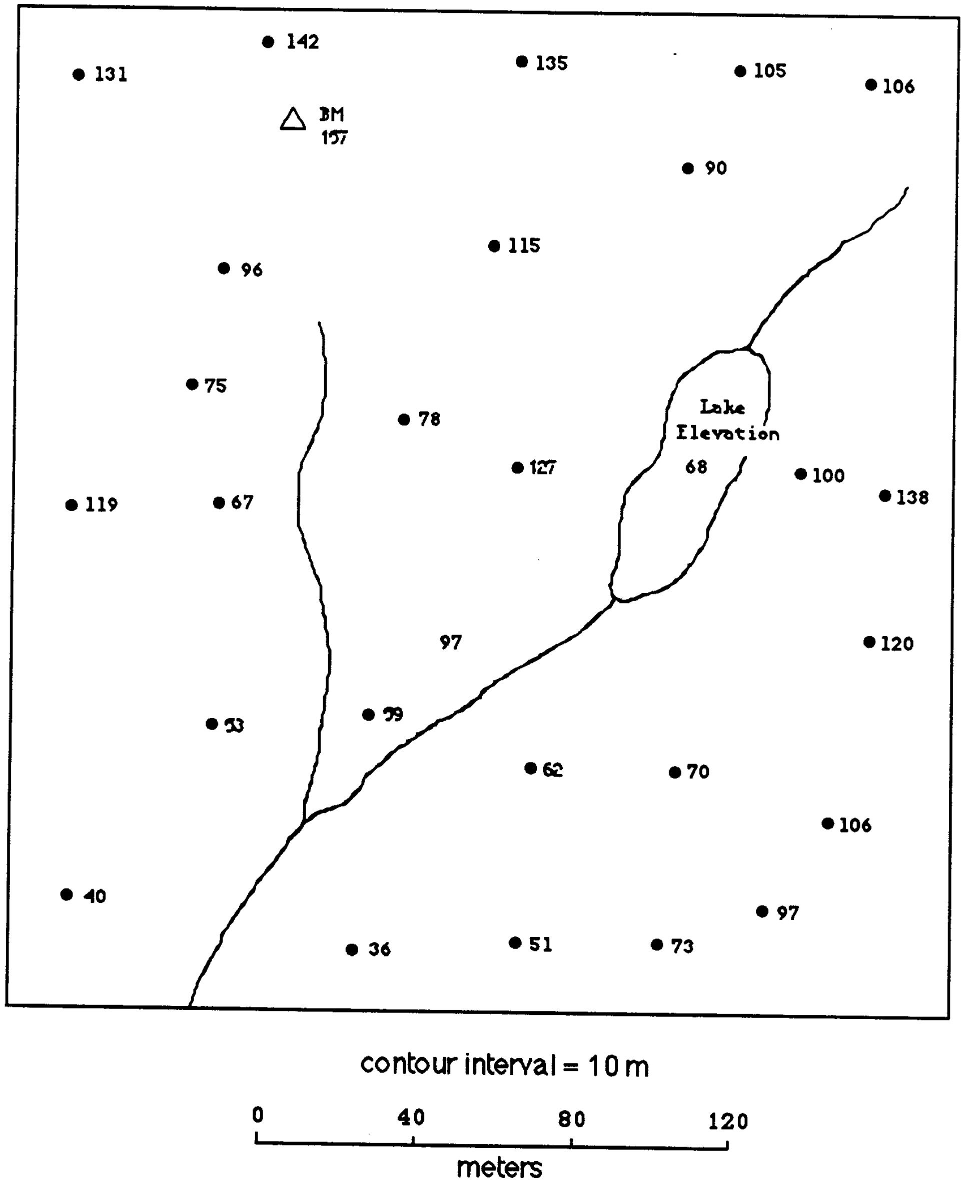
   ____

7. Why is it that contour lines cannot cross, merge or split? ***(3 pts)***

   ____

   ____

8. Construct a topographic map form the elevations given on the map below. Use a contour interval of 10 meters. Carefully label your contour lines or use color and a key to explain what elevations the lines correspond to. ***(8 pts)***



Use the Pasadena, CA 7.5' Quadrangle map to answer the following questions.

8. What is the longitude of the northwest corner of the map? ***(2 pts)***

____

9. What is the longitude of the southwest corner of the map? ***(2 pts)***

____

10. The western boundary of the map is therefore a line of longitude. Is it east or west longitude? ***(1 pt)***

    ____

11. What is the latitude of the northeast corner? ***(2 pts)*** _________________

12. What is the latitude of the northwest corner? ***(2 pts)*** _________________

13. What is the latitude and longitude of the intersection of Fair Oaks Ave. and California Blvd. to the nearest 30" of arc? ***(3 pts)***

    ____

14. What is the contour interval used on this map (include units!)? ***(1 pt)***

    ____

15. What is the elevation of the intersection of Colorado Blvd. and Lake Ave.?***(2 pts)***

    ____

16. What is the elevation on Lake Ave. two miles north of this intersection? ***(2 pts)***

    ____

17. What is the slope of Lake Ave. in feet/mile between the locations in question 9 and 10? *Hint: Divide the difference in elevation between the two points by the distance between them)* ***(3 pts)***

    ____

18. What is the elevation of the intersection of Lake Ave. & New York Dr.? ***(2 pts)***

    ____

19. What is the elevation on Lake Ave. 3/4 mile north of this intersection? ***(2 pts)***

    ____

20. What is the slope of Lake Ave. in feet/mile between the locations in questions 12 and 13? ***(3 pts)***

    ____

21. What observation about the contour lines on the map supports the difference in your answers to questions 11 and 14? ***(2 pts)***______________________________

    ____

22. Locate the upper Arroyo Seco and find the gaging station where the 1400' contour line crosses the stream. Notice that the contour line makes a distinct "V" with the tip of the V pointing upstream. From the gaging station, in which direction would you go to hike to the nearest paved road?____________How would a hike from the gaging station to the nearest paved road compare with a hike from the station to JPL? ***(2 pts)***____________________________________

    ____

23. Locate 5 debris basins on this map and list them below. What factors do you think influenced the location of these basins? ***(2 pts)***___________________________

    ____

Use the Idyllwild, CA 7.5' Quadrangle map to answer the following questions.

24. Is Lake Hemet a natural or man-made lake? ***(1 pt)***_____________________

25. Which stream contributes the most water to the lake? Why? ***(2 pts)***

    ____

    ____

26. How much would the water in Lake Hemet have to rise in order to flood the landing strip in Garner Valley? ***(2 pts)***______________________

27. What datum is used for this map? ***(1 pt)***____________________

28. What UTM grid zone is it in? ***(1 pt)***_______________________

29. What is the size of each UTM grid square on this map? ***(1 pt)***_______________

30. What is the location in UTM coordinates of the southeastern end of the landing strip in Garner Valley to the nearest 10 meters? ***(3 pts)***_____________________

Use the Mammoth Mtn., CA 7.5' Quadrangle map to answer the following questions.

31. What is the contour interval on this map? ***(1 pt)***_________________________

32. Locate Inyo Crater Lakes near the east edge of the map. What do the "teeth" on contour lines around the lakes mean? ***(2 pts)***_____________________________

33. What is the maximum elevation of the water surface of the southern Inyo Crater Lake? ***(2 pts)***____________Is this elevation in meters or feet?_____________

34. What are the two brown areas in the northeastern part of the map? ***(2 pts)***

    ____

35. In the space below, construct a topographic profile along the route the gondola takes from the Mammoth Mtn. Main Lodge to the top of Mammoth Mountain. Be sure to label the elevations on the profile. ***(5 pts)***

36. What is the approximate vertical exaggeration in the profile above? (That is, how much steeper is the slope in the profile than it is in reality?) ***(2 pts)***

____

37. Locate the boundary line between Mono and Madera Counties. Do any streams flow across this boundary? Why? ***(2 pts)***________________________________

____

Use the Mt. Pinchot, CA 7.5' Quadrangle map to answer the following questions.

38. What is the elevation of Window Peak (at $^{3}\mathbf{70}^{060}$E, $^{40}\mathbf{83}^{470}$N)? ***(2 pts)***__________

39. What is the elevation of $^{3}\mathbf{70}^{750}$E, $^{40}\mathbf{83}^{460}$N? ***(2 pts)***______________________

40. What is the relief (difference in elevation) between Window Peak and the lake in the question above? ***(2 pts)*** ________________________

41. Suggest why Bench Lake got its name. ***(2 pts)***____________________________

42. What feature is at $^{3}\mathbf{74}^{970}$E, $^{40}\mathbf{89}^{780}$N? ***(2 pts)***______________________________

43. What are the UTM coordinates for Mount Ickes? ***(2 pts)***____________________

44. What feature is at $^{3}\mathbf{67}^{100}$E, $^{40}\mathbf{88}^{150}$N? ***(2 pts)***______________________________

45. What is the feature at $^{3}\mathbf{67}^{350}$E, $^{40}\mathbf{91}^{750}$N? ***(2 pts)***___________________________